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PHOTOMETRIC OBSERVATIONS OF SELECTED, OPTICALLY BRIGHT QUASARS FOR SPACE INTERFEROMETRY MISSION AND OTHER FUTURE CELESTIAL REFERENCE FRAMES

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ABSTRACT

Photometric observations of 235 extragalactic objects that are potential targets for the Space Interferometry Mission (SIM) are presented. Mean *B*, *V*, *R*, *I* magnitudes at the 5% level are obtained at 1–4 epochs between 2005 and 2007 using the 1 m telescopes at Cerro Tololo Inter-American Observatory and the Naval Observatory Flagstaff Station. Of the 134 sources that have *V* magnitudes in the Veron & Veron-Cetty catalog, a difference of over 1.0 mag is found for the observed-catalog magnitudes for about 36% of the common sources, and 10 sources show over 3 mag difference. Our first set of observations presented here form the basis of a long-term photometric variability study of the selected reference frame sources to assist in mission target selection and to support QSO multicolor photometric variability studies in general.

Key words: astrometry – galaxies: photometry – quasars: general – reference systems

Online-only material: machine-readable and VO tables

1. INTRODUCTION

The Space Interferometry Mission (SIM) is a proposed facility of the National Aeronautics and Space Administration (NASA) that will be the first space-based Michelson interferometer for astrometry. The version of SIM described here is SIM-Lite (Unwin et al. 2009). It will have a 6 m baseline and operate in the optical/near-IR wave band. For stars brighter than $V = 20$, it will deliver a global astrometric accuracy of 4 μas. When operating in its narrow angle mode, it will achieve a positional accuracy of 1.0 μas for a single measurement, with even smaller errors for differential positional accuracy at the end of five years (the nominal mission lifetime). This performance is at least 2 orders of magnitude better than any existing instrument. Astrometry at these unprecedented levels of precision will significantly impact a broad range of astronomy, from the search for planetary systems to a more accurate value of the Hubble constant, from measurements of dynamical masses of binary stars to the dynamics of accretion disks around supermassive black holes (Unwin et al. 2008).

A key contribution of SIM will be the creation of a new absolute reference frame. The International Celestial Reference Frame (ICRF) is currently the fundamental celestial reference frame and the standard frame for all astrometry. It is defined by the radio positions of 212 extragalactic radio sources with most having errors below 1 mas (Johnston et al. 1995; Ma et al. 1998). SIM will be capable of defining a celestial reference frame at optical/near-IR wavelengths, which will have orders of magnitude greater accuracy than the ICRF with an expected level of about 4 μas. The SIM reference frame will be defined by the positions and motions of 1304 reference grid stars uniformly distributed over the entire sky. The SIM grid stars are selected K0III stars of visual magnitude 10–12. The positions of these grid stars will be determined (end of mission) relative to one another to an accuracy of $<$4 μas in position and parallax and $<$4 μas yr^{-1} in proper motion, with individual observations being accurate to 10 μas.

In order to remove any residual rotation in the SIM stellar reference frame, i.e., to make the frame quasi-inertial, and enable the determination of absolute proper motions, a number of extragalactic sources will be observed by SIM. These distant sources are assumed to have negligible proper motions and parallax. In theory, a minimum of two fixed extragalactic objects needs to be observed for this purpose. In practice, possible structure and variability of the extragalactic sources and zonal errors in the SIM stellar grid solution dictate that a global distribution of at least 20–50 extragalactic sources be used (Makarov et al. 2006). Besides making the SIM reference frame inertial for dynamical applications, the orientation of this new reference frame will be aligned to the current ICRF by observing a subset of the ICRF extragalactic sources that display bright, optical counterparts.

SIM is a pointed mission and only a limited number of targets can be observed. Although targets as faint as 20th magnitude can be observed with SIM to full accuracy, the required observing time is prohibitive for a large number of targets. We wish to minimize observing time for SIM by finding the brightest, suitable sources possible and by ensuring a good all-sky distribution required to establish an inertial reference frame for SIM global astrometry. The goal is to select mainly $R \leqslant 16^m$ QSO targets with some fainter sources to fill in gaps in the sky coverage.

Here, we present the results from photometric observations of potential SIM quasar targets in the Johnson *B*, *V*, *R*, and *I* bands. This program is a long-term effort, and we plan on continued observations to study variability. Color information is required to be able to derive the expected brightness of a target in the not yet specified SIM instrumental bandpass.

Of course these observations will also serve the wider astronomical community. For example, the fully funded Joint Milli-Arcsecond Path-finder Survey (J-MAPS) mission (Gaume et al. 2009), whose goal is to generate a nearly 40 million star catalog with better than 1 mas positional accuracy and photometry to the 1% accuracy level or better, will also need to

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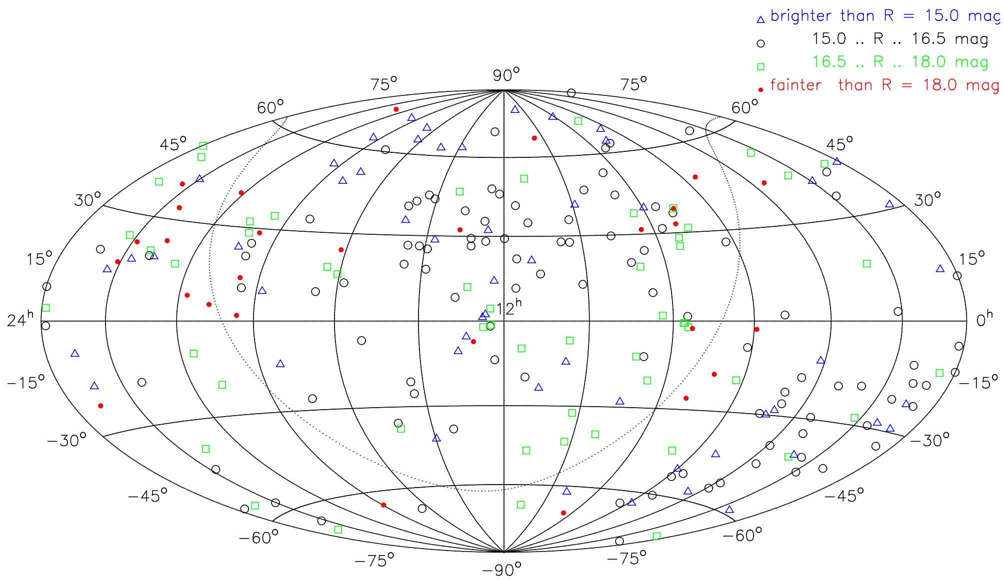

Figure 1. Sky distribution (Aitoff plot) of observed sources. Symbol types indicate *R* magnitude.

Table 1
Summary of Observations

Telescope	Epoch	Label	Nights
NOFS	2005.28	n51	4
NOFS	2005.66	n52	3
NOFS	2006.15	n53	3
NOFS	2007.53	n54	3
CTIO	2005.86	c02	4
CTIO	2006.29	c03	4
CTIO	2006.92	c05	12
CTIO	2007.15	c06	5

observe quasars. Observations of over 100 quasars (which being at large distances have quasi-zero parallax) will be needed in order to make the J-MAPS parallaxes absolute and to minimize zonal parallax errors. Due to their quasi-zero proper motions, observations of quasars will also be needed to make the J-MAPS coordinate system inertial so that J-MAPS astrometry will be relevant to any dynamics study. Finally, observations of quasars will be needed to align the J-MAPS coordinates to the standard system (ICRF) at the mean epoch of observations. Such an alignment is essential for direct positional comparisons of targets common to the J-MAPS optical and the ICRF radio systems.

Finally, despite lots of recent new observations (Wilhite et al. 2008; Bachev 2009; Bauer et al. 2009), quasar variability remains a poorly understood phenomenon and our data set will allow us to begin addressing questions such as the mechanisms that give rise to quasar variability (e.g., see Vanden Berk et al. 2004 and references therein).

2. OBSERVATIONS

With the ultimate goal of selecting suitable, compact, optically bright QSOs for a future astrometric celestial reference frame that will be established by a mission like SIM, 242 extragalactic sources preferably brighter than 16th visual magnitude and with no noticeable asymmetric structure on the Digitized Sky Survey images as compared to nearby stellar objects were chosen by visual inspection from the Veron-Cetty catalog (Véron-Cetty & Véron 2006, hereafter VCV06). Photometric observations of these sources were carried out in the Johnson *B*, *V*, *R*, and *I* bands and results for 214 of these sources are presented along with an additional 21 sources which were observed as part of related observing programs.

Objects in the northern hemisphere were primarily observed with the Naval Observatory Flagstaff Station (NOFS) 1.0 m Ritchey-Chretièn reflector, using a 2k CCD camera during four observing runs between 2005 and 2007. Objects in the southern hemisphere were observed with the Cerro Tololo Inter-American Observatory (CTIO) Small and Moderate Aperture Research Telescope System (SMARTS) 1.0 m in Chile. The 4k×4k pixel camera Y4KCam was used and four successful observing runs were carried out from 2005 through 2007. The epochs and lengths of all successful observing runs with both telescopes are summarized in Table 1. Standard photometric calibration observations were performed as part of these runs, including dome flats and observations of Landolt calibration stars (Landolt 1992).

3. DATA REDUCTION

3.1. Raw Data Processing

For the CTIO 1 m data, modified scripts based on the 4k CCD processing pipeline developed by P. Massey[4] in IRAF[5] were used for overscan, trim, bias, and flat-field operations (four-output system from Yale University). Standard IRAF routines were used for the raw data processing from the single output 2k CCD used at the NOFS 1 m telescope. All individual bias and flat frames were looked at and only acceptable data were used for combining.

3.2. Astrometric Data Processing

All processed object frames were examined visually and the QSO target was identified with respect to finder charts. Basic statistical information and remarks were entered in a quality control table. The astrometric pipeline of the radio-optical

4 http://www.lowell.edu/users/massey/obins/y4kcamred.html

5 IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

Table 2
Magnitudes of SIM Candidate Quasars

Source	Mean *B*	Mean *V*	Mean *R*	Mean *I*	Stdd *B*	Stdd *V*	Stdd *R*	Stdd *I*	*B*−*V*	*V*−*R*	*R*−*I*	*V*−*I*	*nB*	*nV*	*nR*	*nI*	Epoch
0000−128	15.646	15.516	15.312	14.645	0.007	0.007	0.003	0.008	0.130	0.205	0.667	0.871	2	3	3	3	c05
0001+113	16.354	16.155	15.894	15.244	0.028	0.014	0.015	0.015	0.199	0.261	0.650	0.911	1	1	1	1	n52
0001+113	16.443	16.396	16.066	15.346	0.001	0.027	0.003	0.029	0.047	0.330	0.720	1.050	2	1	2	1	c05
0006+437	14.851	14.621	14.402	13.850	0.029	0.020	0.021	0.019	0.230	0.219	0.552	0.771	1	1	1	1	n52
0010−063	17.438	16.555	15.973	15.367	0.029	0.019	0.004	0.001	0.882	0.582	0.606	1.188	4	2	4	2	c05
0010−063	17.774	16.275	15.683	14.993	0.029	0.014	0.014	0.015	1.499	0.592	0.690	1.282	1	1	1	1	n52
0017+816	17.605	16.524	···	15.688	0.024	0.017	···	0.017	1.081	9.900	9.900	0.836	1	1	0	1	n52
0028+311	15.467	15.218	14.971	14.634	0.029	0.020	0.021	0.019	0.249	0.247	0.337	0.584	1	1	1	1	n52
0029+133	15.253	15.170	14.854	14.256	0.017	0.031	0.002	0.019	0.083	0.316	0.599	0.914	2	1	2	1	c05
0029+133	15.354	15.096	14.812	···	0.028	0.014	0.014	···	0.258	0.284	9.900	9.900	1	1	1	0	n52
0030−134	18.350	17.345	16.728	16.043	0.032	0.023	0.010	0.003	1.005	0.617	0.686	1.302	1	3	3	3	c05
0034−339	17.420	16.785	16.347	15.795	0.016	0.003	0.011	···	0.635	0.438	0.552	0.990	4	2	4	2	c05
0034−339	17.708	16.964	16.513	15.882	0.024	0.027	0.028	0.068	0.744	0.451	0.631	1.082	1	1	1	1	c02
0034−704	17.337	17.343	17.139	16.800	0.075	0.021	0.013	0.057	−0.006	0.204	0.340	0.543	3	1	2	1	c05
0034−704	17.474	17.425	17.171	16.824	0.022	0.019	0.023	0.079	0.049	0.254	0.347	0.601	1	1	1	1	c02
0037+444	17.742	17.509	17.273	16.953	0.024	0.017	0.015	0.018	0.233	0.236	0.320	0.556	1	1	1	1	n52
0041−226	···	16.897	16.195	15.647	···	0.021	0.037	0.055	9.900	0.702	0.548	1.250	0	2	3	3	c05
0043−169	16.472	16.433	16.189	15.725	0.025	0.020	0.043	0.071	0.039	0.244	0.464	0.708	2	1	3	1	c05
0045−291	15.634	15.082	14.679	14.358	0.014	0.006	0.022	0.003	0.552	0.403	0.321	0.724	3	3	3	3	c05
0045−291	15.797	15.166	14.817	14.435	0.023	0.027	0.028	0.068	0.631	0.349	0.382	0.731	1	1	1	1	c02
0056−752	16.917	16.398	15.891	15.345	0.010	0.008	0.016	0.015	0.519	0.507	0.546	1.053	3	3	3	3	c05
0056−752	16.973	16.420	15.938	15.372	0.021	0.018	0.023	0.079	0.553	0.482	0.566	1.048	1	1	1	1	c02
0057−224	14.598	14.493	14.283	14.084	0.017	0.014	0.015	0.018	0.105	0.210	0.200	0.409	3	3	3	3	c05
0101+425	16.539	16.325	16.026	15.356	0.023	0.017	0.014	0.017	0.214	0.299	0.670	0.969	1	1	1	1	n52
0110−168	16.560	16.357	16.169	15.863	0.012	0.020	0.019	0.029	0.203	0.189	0.306	0.495	3	3	3	3	c05
0114−424	15.783	15.631	15.353	14.864	0.018	0.014	0.015	0.031	0.152	0.278	0.489	0.767	5	4	5	4	c05
0114−424	16.107	15.873	15.531	15.015	0.024	0.024	0.024	0.054	0.234	0.342	0.516	0.858	1	1	1	1	c02
0121−283	14.731	14.689	14.470	14.191	0.004	0.016	0.004	0.008	0.042	0.219	0.278	0.497	3	3	3	3	c05
0121−283	15.151	15.039	14.826	14.558	0.024	0.024	0.024	0.054	0.112	0.213	0.268	0.481	1	1	1	1	c02
0123−588	13.817	13.697	13.345	13.048	0.010	0.022	0.017	0.023	0.120	0.352	0.297	0.649	2	3	2	3	c05
0123−588	14.084	13.907	13.547	13.270	0.021	0.018	0.023	0.079	0.177	0.360	0.277	0.637	1	1	1	1	c02
0124−120	17.293	16.506	15.991	15.397	0.027	0.030	0.024	0.036	0.787	0.515	0.594	1.109	3	3	3	3	c05
0131−216	16.868	16.795	16.478	15.919	0.005	0.011	0.011	0.015	0.073	0.317	0.558	0.876	2	3	3	3	c05
0131−216	16.950	16.809	16.511	15.969	0.024	0.027	0.028	0.068	0.141	0.298	0.542	0.840	1	1	1	1	c02
0135−294	16.475	16.303	16.176	15.867	0.015	0.005	0.017	0.033	0.171	0.127	0.310	0.437	3	3	3	3	c05
0150+362	17.220	16.373	15.808	15.155	0.029	0.020	0.021	0.019	0.847	0.565	0.653	1.218	1	1	1	1	n52
0155−451	15.408	15.777	15.239	15.715	0.003	0.169	0.007	0.007	−0.370	0.538	−0.476	0.062	2	3	2	2	c05
0155−451	15.593	15.507	15.366	15.321	0.021	0.018	0.023	0.079	0.086	0.141	0.045	0.186	1	1	1	1	c02
0157+413	17.997	15.449	14.585	···	0.032	0.020	0.021	···	2.548	0.864	9.900	9.900	1	1	1	0	n52
0207+027	15.522	15.358	15.223	14.761	0.016	0.028	0.018	0.040	0.164	0.135	0.462	0.597	3	3	3	3	c05
0207+027	15.644	15.412	15.269	14.801	0.028	0.014	0.014	0.015	0.232	0.143	0.468	0.611	1	1	1	1	n52
0212−279	16.985	16.854	16.676	16.327	0.024	0.027	0.028	0.068	0.131	0.178	0.349	0.527	1	1	1	1	c02
0212−279	17.008	16.857	16.704	16.360	0.023	0.022	0.012	0.021	0.150	0.153	0.344	0.498	6	6	6	4	c05
0222+524	19.300	17.997	17.224	···	0.031	0.021	0.021	···	1.303	0.773	9.900	9.900	1	1	1	0	n52
0227+442	18.458	17.973	17.624	···	0.030	0.021	0.021	···	0.485	0.349	9.900	9.900	1	1	1	0	n52
0228−410	15.355	15.299	15.052	14.790	0.009	0.011	0.004	0.008	0.056	0.247	0.263	0.510	7	5	7	5	c05
0228−410	15.396	15.246	14.992	14.775	0.152	0.151	0.137	0.120	0.150	0.254	0.217	0.471	1	1	1	1	c02
0238+166	···	17.963	17.184	16.159	···	0.031	0.078	0.113	9.900	0.779	1.025	1.804	0	4	3	4	c05
0240−189	15.390	15.319	15.182	14.844	0.021	0.011	0.012	0.006	0.071	0.137	0.337	0.474	3	3	3	3	c05
0244+625	19.289	17.426	16.278	15.146	0.035	0.021	0.021	0.019	1.863	1.148	1.132	2.280	1	1	1	1	n52
0248−408	15.281	15.062	14.901	14.733	0.021	0.018	0.023	0.079	0.219	0.161	0.168	0.329	1	1	1	1	c02
0248−408	15.357	15.101	14.948	14.736	0.006	0.029	0.010	0.049	0.256	0.152	0.213	0.365	3	3	3	3	c05
0254−416	···	17.919	17.245	16.484	···	0.151	0.137	0.120	9.900	0.674	0.761	1.435	0	1	1	1	c02
0254−416	18.708	17.854	17.251	16.572	0.069	0.016	0.020	0.031	0.855	0.602	0.679	1.282	7	5	7	5	c05
0318−344	16.041	15.975	15.737	15.181	0.152	0.151	0.137	0.120	0.066	0.238	0.556	0.794	1	1	1	1	c02
0318−344	16.305	16.299	16.013	15.390	0.012	0.064	0.013	0.028	0.006	0.286	0.623	0.909	6	5	5	4	c05
0320−194	17.366	16.621	16.149	15.603	0.067	0.023	0.018	0.032	0.746	0.472	0.546	1.018	3	3	3	3	c05
0331−294	15.969	15.870	15.668	15.382	0.016	0.017	0.015	0.026	0.099	0.202	0.286	0.488	5	4	5	4	c05
0331−294	15.996	15.881	15.691	15.403	0.023	0.027	0.028	0.068	0.115	0.190	0.288	0.478	1	1	1	1	c02
0334+435	22.366	20.987	20.803	···	0.046	0.023	0.024	···	1.379	0.184	9.900	9.900	1	1	1	0	n53
0338−452	17.009	16.564	16.200	15.702	0.152	0.151	0.137	0.120	0.445	0.364	0.498	0.862	1	1	1	1	c02
0338−452	17.040	16.632	16.261	15.739	0.005	0.027	0.021	0.009	0.408	0.371	0.522	0.893	4	4	5	4	c05
0350−527	16.409	16.252	15.873	15.521	0.010	0.011	0.006	0.011	0.157	0.379	0.352	0.731	3	3	3	3	c05
0350−527	16.420	16.257	15.882	15.545	0.024	0.024	0.024	0.054	0.163	0.375	0.337	0.712	1	1	1	1	c02
0355−392	16.199	15.939	15.747	15.568	0.012	0.006	0.017	0.016	0.260	0.192	0.179	0.371	5	4	5	4	c05
0355−392	16.202	15.940	15.770	15.649	0.021	0.018	0.023	0.079	0.262	0.170	0.121	0.291	1	1	1	1	c02
0355−549	16.331	16.274	16.027	15.539	0.021	0.018	0.023	0.079	0.057	0.247	0.488	0.735	1	1	1	1	c02

Table 2
(Continued)

Source	Mean *B*	Mean *V*	Mean *R*	Mean *I*	Stdd *B*	Stdd *V*	Stdd *R*	Stdd *I*	*B*−*V*	*V*−*R*	*R*−*I*	*V*−*I*	*nB*	*nV*	*nR*	*nI*	Epoch
0355−549	16.404	16.343	16.083	15.539	0.009	0.002	0.005	0.007	0.060	0.260	0.545	0.805	3	3	3	3	c05
0407−122	14.644	14.475	14.305	13.983	0.008	0.003	0.003	0.011	0.169	0.170	0.321	0.492	7	6	10	5	c05
0426−572	14.375	14.274	14.085	13.915	0.021	0.018	0.023	0.079	0.101	0.189	0.170	0.359	1	1	1	1	c02
0426−572	14.912	14.669	14.435	14.257	0.015	0.006	0.009	0.010	0.243	0.234	0.178	0.412	4	5	4	5	c05
0428−176	15.783	15.810	15.489	14.775	0.005	0.122	0.008	0.020	−0.027	0.320	0.714	1.034	7	6	7	5	c05
0438−261	16.630	16.424	16.206	15.801	0.015	0.008	0.013	0.014	0.206	0.219	0.405	0.624	4	4	3	3	c05
0438−261	16.757	16.528	16.344	16.023	0.024	0.024	0.024	0.054	0.229	0.184	0.321	0.505	1	1	1	1	c02
0443−283	15.256	15.128	14.944	14.631	0.037	0.005	0.020	0.011	0.128	0.184	0.313	0.497	5	4	5	4	c05
0443−283	15.283	15.121	14.974	14.674	0.023	0.027	0.028	0.068	0.162	0.147	0.300	0.447	1	1	1	1	c02
0444−224	17.857	17.081	16.495	15.903	0.025	0.024	0.024	0.054	0.776	0.586	0.592	1.178	1	1	1	1	c02
0444−224	17.868	17.066	16.460	15.868	0.031	0.031	0.007	0.002	0.803	0.606	0.592	1.198	2	3	3	3	c05
0452−299	15.311	15.057	14.748	14.301	0.028	0.019	0.039	0.030	0.253	0.310	0.446	0.756	5	4	5	4	c05
0452−299	15.462	15.182	14.874	14.458	0.023	0.027	0.028	0.068	0.280	0.308	0.416	0.724	1	1	1	1	c02
0504−297	16.187	16.210	16.151	15.844	0.032	0.014	0.013	0.024	−0.022	0.059	0.307	0.366	3	3	3	3	c05
0504−297	16.239	16.173	16.113	15.873	0.024	0.024	0.024	0.054	0.066	0.060	0.240	0.300	1	1	1	1	c02
0504−297	16.277	16.276	16.201	15.923	0.004	0.011	0.001	···	···	0.076	0.278	0.354	2	2	2	2	c06
0513+019	···	17.351	16.483	15.755	···	0.153	0.038	0.019	9.900	0.869	0.727	1.596	0	2	2	2	c06
0517−442	15.437	15.203	14.850	14.342	0.005	0.007	0.011	0.024	0.234	0.353	0.508	0.861	2	2	2	2	c06
0517−442	15.453	15.201	14.842	14.350	0.003	0.003	0.010	0.019	0.252	0.359	0.493	0.852	3	3	3	3	c05
0517−442	15.536	15.253	14.913	14.368	0.023	0.027	0.028	0.068	0.283	0.340	0.545	0.885	1	1	1	1	c02
0533+484	···	20.445	19.860	18.975	···	0.021	0.020	0.016	9.900	0.585	0.885	1.470	0	1	1	1	n53
0534−603	18.064	17.088	16.475	15.910	0.153	0.151	0.137	0.120	0.976	0.613	0.565	1.178	1	1	1	1	c02
0534−603	18.125	17.132	16.492	15.921	0.034	0.052	0.010	0.020	0.993	0.640	0.571	1.211	4	5	8	5	c05
0534−603	18.134	17.156	16.487	15.880	0.047	0.017	0.010	0.033	0.978	0.669	0.606	1.275	2	2	2	2	c06
0536−517	16.679	16.148	15.745	15.148	0.024	0.027	0.028	0.068	0.531	0.403	0.597	1.000	1	1	1	1	c02
0536−517	16.778	16.229	15.799	15.211	0.024	0.003	0.006	0.029	0.548	0.431	0.588	1.019	3	4	4	3	c05
0536−517	16.786	16.254	15.799	15.208	0.006	0.026	0.009	0.045	0.532	0.456	0.590	1.046	2	2	2	2	c06
0552−532	15.901	15.729	15.349	14.975	0.007	0.019	0.009	0.009	0.172	0.381	0.374	0.754	5	4	5	4	c05
0552−532	15.949	15.745	15.370	14.973	0.006	0.005	0.002	0.023	0.204	0.375	0.397	0.772	2	2	2	2	c06
0552−532	15.964	15.737	15.365	14.981	0.023	0.027	0.028	0.068	0.227	0.372	0.384	0.756	1	1	1	1	c02
0552−640	15.354	15.153	14.906	14.493	0.007	···	0.007	0.012	0.201	0.246	0.413	0.659	2	2	2	2	c06
0552−640	15.392	15.176	14.939	14.528	0.006	0.012	0.011	0.004	0.216	0.237	0.411	0.649	5	4	5	4	c05
0552−640	15.633	15.405	14.884	14.597	0.152	0.151	0.137	0.120	0.228	0.521	0.287	0.808	1	1	1	1	c02
0556−027	···	···	19.071	18.119	···	···	0.052	0.046	···	9.900	0.952	9.900	0	0	6	4	c05
0556−027	···	20.278	19.017	18.156	···	0.025	0.113	0.045	9.900	1.261	0.861	2.122	0	1	2	2	c06
0556−027	···	20.493	19.271	18.496	···	0.021	0.037	0.045	9.900	1.222	0.775	1.997	0	1	1	1	n53
0559−504	15.084	14.943	14.798	14.406	0.015	0.004	0.004	0.021	0.141	0.145	0.392	0.537	2	2	2	2	c06
0559−504	15.101	14.967	14.814	14.426	0.008	0.009	0.009	0.008	0.134	0.154	0.388	0.541	3	3	3	3	c05
0559−504	15.131	14.979	14.836	14.482	0.024	0.024	0.024	0.054	0.152	0.143	0.354	0.497	1	1	1	1	c02
0607−086	···	16.764	15.782	14.504	···	0.027	0.028	0.068	9.900	0.982	1.278	2.260	0	1	1	1	c02
0607−086	18.133	16.682	15.658	14.480	0.076	0.001	0.008	0.016	1.451	1.024	1.179	2.202	3	3	3	3	c05
0607−086	18.202	16.764	15.719	14.530	0.014	0.026	0.019	0.023	1.438	1.045	1.189	2.234	2	2	2	2	c06
0607−086	18.290	16.805	15.797	14.551	0.013	0.012	0.036	0.044	1.485	1.008	1.246	2.254	1	1	1	1	n53
0611−194	···	17.738	17.146	16.237	···	0.001	0.028	0.068	9.900	0.592	0.909	1.501	0	2	1	1	c02
0611−194	18.810	17.608	17.049	16.232	0.032	0.016	0.029	0.051	1.202	0.559	0.816	1.376	1	2	2	2	c06
0611−194	18.879	17.864	17.013	16.177	0.001	0.148	0.026	0.017	1.015	0.851	0.836	1.686	2	6	1	2	c05
0613+261	18.635	17.554	16.654	16.239	0.014	···	0.258	0.043	1.081	0.900	0.415	1.315	2	2	3	3	c05
0623−646	16.226	15.965	15.622	15.017	0.014	0.009	0.002	0.023	0.260	0.344	0.604	0.948	2	2	2	2	c06
0630+691	14.571	14.408	14.131	13.789	0.013	0.011	0.014	0.012	0.163	0.277	0.342	0.619	1	1	1	1	n53
0646−443	···	17.192	16.888	16.304	···	0.017	0.016	0.018	9.900	0.304	0.584	0.888	0	1	1	1	c03
0646−443	17.513	17.152	16.921	16.319	0.020	0.012	0.018	0.041	0.361	0.231	0.602	0.833	6	4	5	4	c05
0646−443	17.550	17.198	16.911	16.283	0.025	0.024	0.024	0.054	0.352	0.287	0.628	0.915	1	1	1	1	c02
0646−443	17.743	17.323	17.037	16.373	0.018	0.008	0.016	0.030	0.420	0.286	0.664	0.950	2	2	2	2	c06
0648−177	···	···	18.644	···	···	···	0.029	···	···	9.900	9.900	···	0	0	1	0	c02
0648−177	···	19.071	18.448	17.994	···	0.024	0.014	0.056	9.900	0.622	0.455	1.077	0	1	2	1	c05
0648−177	19.768	19.089	18.494	17.965	0.048	0.033	0.007	0.087	0.679	0.595	0.529	1.124	1	2	2	2	c06
0648−177	19.944	19.195	18.575	18.168	0.063	0.026	0.018	0.020	0.749	0.620	0.407	1.027	2	1	1	1	c03
0654+733	19.378	17.212	16.622	15.765	0.028	0.015	0.023	0.012	2.166	0.590	0.857	1.447	1	1	1	1	n53
0702+316	17.498	17.054	16.778	16.580	0.046	0.037	0.034	0.048	0.444	0.276	0.198	0.474	1	1	1	1	n51
0705+636	15.605	15.378	15.164	14.591	0.012	0.013	0.022	0.011	0.227	0.214	0.573	0.787	1	1	1	1	n53
0705+636	15.683	15.444	15.272	14.674	0.070	0.036	0.037	0.055	0.239	0.172	0.598	0.770	1	1	1	1	n51
0707+384	18.914	···	19.463	18.311	0.110	···	0.095	0.085	9.900	9.900	1.152	9.900	1	0	1	1	n51
0707+385	17.142	···	17.203	16.943	0.109	···	0.093	0.084	9.900	9.900	0.260	9.900	1	0	1	1	n51
0707+646	15.382	15.047	14.677	14.156	0.070	0.036	0.037	0.045	0.335	0.370	0.521	0.891	1	1	1	1	n51
0707+646	15.605	15.163	14.693	14.175	0.013	0.012	0.014	0.012	0.442	0.470	0.518	0.988	1	1	1	1	n53
0713+369	15.885	15.719	15.767	15.310	0.061	0.078	0.090	0.055	0.166	−0.048	0.457	0.409	1	1	1	1	n51

Table 2
(Continued)

Source	Mean B	Mean V	Mean R	Mean I	Stdd B	Stdd V	Stdd R	Stdd I	$B-V$	$V-R$	$R-I$	$V-I$	nB	nV	nR	nI	Epoch
0718−261	19.021	18.544	18.143	17.711	0.026	0.025	0.024	0.055	0.477	0.401	0.432	0.833	1	1	1	1	c02
0718−261	19.060	18.646	18.221	17.699	0.034	0.016	0.013	0.058	0.414	0.425	0.522	0.947	3	3	3	3	c05
0718−261	19.071	18.689	18.203	17.716	0.054	0.060	0.010	0.017	0.382	0.486	0.487	0.973	2	2	2	2	c06
0718−261	19.078	18.627	18.152	···	0.029	0.014	0.012	···	0.451	0.475	9.900	9.900	1	1	1	0	c03
0719+331	20.304	19.604	19.354	···	0.022	0.017	0.037	···	0.700	0.250	9.900	9.900	1	1	1	0	n53
0725+283	18.007	17.567	17.200	16.710	0.004	0.027	0.014	0.029	0.440	0.367	0.490	0.857	2	1	2	1	c05
0729+254	18.194	···	17.659	17.197	0.021	···	0.010	···	9.900	9.900	0.462	9.900	4	0	4	2	c05
0729+254	18.350	17.932	17.270	···	0.003	0.134	0.036	···	0.418	0.662	9.900	9.900	2	2	1	0	n53
0732+620	15.790	15.538	15.300	···	0.046	0.037	0.034	···	0.252	0.238	9.900	9.900	1	1	1	0	n51
0732+620	15.811	15.592	15.298	14.980	0.012	0.013	0.022	0.012	0.219	0.294	0.318	0.612	1	1	1	1	n53
0732−025	19.429	19.003	18.821	18.552	0.030	0.044	0.017	0.067	0.426	0.182	0.269	0.451	1	3	5	2	c05
0732−025	19.537	18.951	18.820	18.542	0.100	0.019	0.021	0.014	0.586	0.130	0.279	0.409	2	2	2	2	c06
0738−021	17.819	17.410	17.131	16.892	0.042	0.019	0.005	0.027	0.409	0.279	0.239	0.518	2	2	2	2	c06
0738−021	17.872	17.388	17.112	16.909	0.014	0.008	0.024	0.031	0.484	0.276	0.204	0.479	3	3	3	3	c05
0738−021	17.998	17.364	16.825	16.583	0.019	0.090	0.372	0.275	0.634	0.539	0.242	0.781	2	1	1	1	c03
0739+016	16.906	16.528	16.034	15.303	0.022	0.003	0.007	0.016	0.378	0.494	0.731	1.226	2	2	2	2	c06
0739+016	17.230	16.899	16.386	15.651	0.054	0.037	0.082	0.048	0.331	0.513	0.735	1.248	3	3	3	3	c05
0739+016	17.593	17.043	16.470	···	0.012	0.013	0.036	···	0.550	0.573	9.900	9.900	1	1	1	0	n53
0745+317	15.996	···	15.757	15.314	0.109	···	0.093	0.084	9.900	9.900	0.443	9.900	1	0	1	1	n51
0745−007	17.473	17.085	16.823	16.381	0.002	0.011	0.025	0.025	0.388	0.262	0.441	0.704	2	2	2	2	c06
0745−007	17.522	17.196	16.844	16.471	0.022	0.002	0.017	0.009	0.325	0.352	0.373	0.725	3	2	1	2	c05
0745−007	17.559	17.097	···	17.630	0.021	0.017	···	0.019	0.462	9.900	9.900	−0.533	1	1	0	1	c03
0758+393	14.765	14.334	14.093	13.553	0.070	0.036	0.037	0.083	0.431	0.241	0.540	0.781	1	1	1	1	n51
0810+760	14.051	13.930	13.734	13.293	0.012	0.012	0.022	0.011	0.121	0.196	0.441	0.637	1	1	1	1	n53
0810+760	14.261	14.046	···	···	0.045	0.037	···	···	0.215	9.900	···	9.900	1	1	0	0	n51
0815+019	16.837	16.799	16.671	16.344	0.015	0.005	0.044	0.010	0.038	0.129	0.327	0.455	3	3	3	3	c05
0815+019	16.854	16.819	16.632	16.349	0.019	0.014	0.006	0.024	0.034	0.188	0.283	0.471	2	2	2	2	c06
0815+019	16.964	16.830	16.390	16.136	0.012	0.090	0.372	0.275	0.134	0.440	0.254	0.694	1	1	1	1	c03
0820+316	20.092	···	19.011	18.840	0.113	···	0.094	0.085	9.900	9.900	0.171	9.900	1	0	1	1	n51
0820+375	···	16.915	16.617	15.461	···	0.078	0.090	0.056	9.900	0.298	1.156	1.454	0	1	1	1	n51
0827+097	17.215	15.975	15.201	14.426	0.033	0.008	0.011	0.013	1.239	0.774	0.775	1.549	3	4	4	5	c05
0827+097	17.239	15.900	14.852	14.117	0.013	0.090	0.372	0.275	1.339	1.048	0.735	1.783	1	1	1	1	c03
0827+097	17.244	15.997	15.209	14.418	0.046	0.038	0.030	0.011	1.247	0.788	0.791	1.579	2	2	2	2	c06
0827+097	17.353	16.075	15.275	···	0.012	0.012	0.035	···	1.278	0.800	9.900	9.900	1	1	1	0	n53
0827−204	17.900	···	···	···	0.029	···	···	···	9.900	···	···	···	1	0	0	0	c03
0827−204	18.034	17.559	17.330	16.970	0.014	0.009	0.045	0.074	0.475	0.229	0.360	0.589	5	5	5	4	c05
0827−204	18.079	17.665	17.447	17.237	0.030	0.022	0.030	0.034	0.414	0.218	0.210	0.428	1	1	1	1	c06
0828−708	···	18.551	18.051	17.541	···	0.025	0.017	0.019	9.900	0.500	0.510	1.010	0	1	1	1	c03
0828−708	19.189	18.418	17.987	17.578	0.036	0.016	0.033	0.058	0.771	0.431	0.409	0.840	2	2	2	2	c06
0828−708	19.399	18.475	17.970	17.421	0.129	0.027	0.034	0.034	0.923	0.506	0.548	1.054	3	3	3	3	c05
0830+241	17.051	16.664	16.269	15.805	0.074	0.031	0.034	0.043	0.387	0.395	0.464	0.859	1	1	1	1	c06
0831+528	18.827	16.448	15.353	14.608	0.017	0.012	0.014	0.012	2.379	1.095	0.745	1.840	1	1	1	1	n53
0831+528	19.111	16.552	15.271	14.534	0.051	0.037	0.034	0.048	2.559	1.281	0.737	2.018	1	1	1	1	n51
0836+444	15.651	15.585	15.378	14.869	0.070	0.036	0.037	0.081	0.066	0.207	0.509	0.716	1	1	1	1	n51
0839−122	16.386	16.296	15.981	15.135	0.011	0.019	0.008	0.041	0.090	0.315	0.846	1.161	3	4	3	3	c05
0839−122	16.490	16.321	15.706	14.867	0.012	0.090	0.372	0.275	0.169	0.615	0.839	1.454	1	1	1	1	c03
0839−122	16.521	16.440	16.076	15.204	0.027	0.020	0.017	0.028	0.082	0.363	0.872	1.236	2	2	2	2	c06
0842+185	17.179	16.966	16.580	16.338	0.074	0.031	0.034	0.043	0.213	0.386	0.242	0.628	1	1	1	1	c06
0850−122	18.014	17.349	17.232	16.266	0.074	0.175	0.001	0.164	0.665	0.117	0.966	1.084	3	4	2	3	c05
0850−122	18.046	17.609	17.116	16.464	0.022	0.017	0.016	0.018	0.437	0.493	0.652	1.145	1	1	1	1	c03
0850−122	18.097	17.709	17.257	16.620	0.080	0.066	0.055	0.064	0.388	0.453	0.636	1.089	2	2	2	2	c06
0854+201	16.147	15.666	15.180	14.567	0.029	0.021	0.030	0.033	0.481	0.486	0.613	1.099	1	1	1	1	c06
0900−281	15.052	14.518	14.358	14.038	0.033	0.124	0.015	0.054	0.533	0.160	0.320	0.481	3	4	3	3	c05
0900−281	15.089	14.641	14.390	14.119	0.021	0.020	0.009	0.023	0.447	0.251	0.271	0.522	2	2	2	2	c06
0915+295	16.602	16.236	15.874	15.384	0.046	0.039	0.037	0.044	0.366	0.362	0.490	0.852	1	1	1	1	c06
0916−623	13.881	13.466	12.910	12.647	0.024	0.015	0.014	0.013	0.415	0.556	0.263	0.819	3	3	3	3	c05
0916−623	13.964	13.523	12.984	12.719	0.009	0.014	0.005	0.009	0.441	0.538	0.266	0.804	2	2	2	2	c06
0916−623	14.013	···	···	···	0.011	···	···	···	9.900	···	···	···	1	0	0	0	c03
0922−400	17.885	17.533	17.302	16.805	0.017	0.014	0.024	0.037	0.352	0.230	0.498	0.728	3	3	3	3	c05
0922−400	17.947	17.624	17.370	16.875	0.029	0.021	0.030	0.033	0.323	0.254	0.495	0.749	1	1	1	1	c06
0922−400	18.062	17.712	17.463	16.963	0.028	0.013	0.012	0.011	0.350	0.249	0.500	0.749	1	1	1	1	c03
0929+467	16.423	16.222	16.094	15.553	0.061	0.078	0.090	0.055	0.201	0.128	0.541	0.669	1	1	1	1	n51
0929+467	16.622	16.515	16.235	15.717	0.012	0.013	0.022	0.012	0.107	0.280	0.518	0.798	1	1	1	1	n53
0956+413	14.605	14.610	14.452	14.066	0.013	0.011	0.014	0.012	−0.005	0.158	0.386	0.544	1	1	1	1	n53
0956+413	14.769	···	···	14.284	0.069	···	···	0.103	9.900	···	9.900	9.900	1	0	0	1	n51
1007+128	15.589	15.427	15.160	14.670	0.016	0.007	0.002	0.009	0.161	0.267	0.490	0.757	2	2	2	2	c06

Table 2
(Continued)

Source	Mean *B*	Mean *V*	Mean *R*	Mean *I*	Stdd *B*	Stdd *V*	Stdd *R*	Stdd *I*	*B*−*V*	*V*−*R*	*R*−*I*	*V*−*I*	*nB*	*nV*	*nR*	*nI*	Epoch
1007+128	15.631	15.452	15.179	···	0.011	0.012	0.035	···	0.179	0.273	9.900	9.900	1	1	1	0	n53
1007+128	15.788	15.412	14.817	14.376	0.011	0.090	0.372	0.275	0.376	0.595	0.441	1.036	1	1	1	1	c03
1011−324	17.479	17.218	16.837	16.338	0.006	0.016	0.007	0.012	0.262	0.381	0.499	0.880	2	2	2	2	c06
1011−324	17.697	17.379	16.969	16.394	0.028	0.013	0.011	0.011	0.318	0.410	0.575	0.985	1	1	1	1	c03
1012−430	17.707	17.057	16.664	16.260	0.021	0.017	0.016	0.018	0.650	0.393	0.404	0.797	1	1	1	1	c03
1012−430	17.728	17.104	16.669	16.281	0.005	0.005	0.013	0.005	0.624	0.435	0.389	0.823	2	2	2	2	c06
1013+359	15.867	15.573	15.253	14.852	0.012	0.013	0.022	0.012	0.294	0.320	0.401	0.721	1	1	1	1	n53
1013+359	16.017	···	15.375	···	0.109	···	0.093	···	9.900	9.900	9.900	···	1	0	1	0	n51
1019+277	16.503	···	15.692	15.225	0.109	···	0.093	0.084	9.900	9.900	0.467	9.900	1	0	1	1	n51
1026+678	18.715	···	···	17.824	0.049	···	···	0.050	9.900	···	9.900	9.900	1	0	0	1	n51
1026+678	19.171	18.770	18.444	18.115	0.019	0.015	0.016	0.015	0.401	0.326	0.329	0.655	1	1	1	1	n53
1027−068	18.362	17.305	···	···	0.017	0.090	···	···	1.057	9.900	···	9.900	1	1	0	0	c03
1027−068	18.897	17.360	16.640	15.937	0.048	0.070	0.016	0.039	1.537	0.719	0.703	1.423	1	2	2	2	c06
1027−068	20.093	16.024	15.530	14.569	0.028	0.012	0.036	0.044	4.069	0.494	0.961	1.455	1	1	1	1	n53
1031−143	13.985	13.896	13.580	13.362	0.028	0.024	0.016	0.018	0.089	0.316	0.218	0.534	1	1	1	1	c03
1031−143	14.149	14.026	13.703	13.452	0.044	0.038	0.033	0.018	0.123	0.323	0.251	0.574	2	2	2	2	c06
1032+279	19.270	···	16.311	15.408	0.112	···	0.093	0.084	9.900	9.900	0.903	9.900	1	0	1	1	n51
1050+802	···	···	···	14.175	···	···	···	0.048	···	···	9.900	9.900	0	0	0	1	n51
1050+802	15.329	15.067	14.865	14.250	0.012	0.013	0.022	0.011	0.262	0.202	0.615	0.817	1	1	1	1	n53
1107+165	16.712	16.573	16.482	···	0.011	0.012	0.036	···	0.139	0.091	9.900	9.900	1	1	1	0	n53
1107+165	16.830	16.491	16.042	15.735	0.012	0.090	0.372	0.275	0.339	0.449	0.307	0.756	1	1	1	1	c03
1107+165	16.890	16.715	16.538	16.137	0.183	0.125	0.075	0.040	0.176	0.177	0.401	0.578	2	2	2	2	c06
1107−683	18.118	17.721	17.447	16.949	0.028	0.014	0.012	0.011	0.397	0.274	0.498	0.772	1	1	1	1	c03
1107−683	18.330	17.927	17.622	17.053	0.019	0.014	0.011	0.031	0.404	0.305	0.569	0.874	2	2	2	2	c06
1108−236	14.811	14.564	14.227	13.946	0.028	0.024	0.016	0.018	0.247	0.337	0.281	0.618	1	1	1	1	c03
1108−236	14.936	14.663	14.336	14.047	0.021	0.016	0.024	0.011	0.273	0.326	0.289	0.616	2	2	2	2	c06
1118−466	17.349	17.021	···	···	0.021	0.017	···	···	0.328	9.900	···	9.900	1	1	0	0	c03
1118−466	17.389	17.108	16.917	16.631	0.017	0.013	0.005	0.020	0.281	0.191	0.286	0.477	2	2	2	2	c06
1119+213	14.246	14.180	14.160	13.702	0.061	0.078	0.090	0.055	0.066	0.020	0.458	0.478	1	1	1	1	n51
1119+213	14.662	14.597	14.377	13.726	0.136	0.088	0.038	0.012	0.065	0.220	0.651	0.872	2	2	2	2	c06
1119+213	14.961	14.650	14.106	13.444	0.011	0.090	0.372	0.275	0.311	0.544	0.662	1.206	1	1	1	1	c03
1119+516	17.704	17.559	17.163	···	0.070	0.036	0.037	···	0.145	0.396	9.900	9.900	1	1	1	0	n51
1121+349	16.476	15.782	15.362	14.855	0.013	0.013	0.022	0.012	0.694	0.420	0.507	0.927	1	1	1	1	n53
1121+349	17.964	···	15.336	···	0.110	···	0.093	···	9.900	9.900	9.900	···	1	0	1	0	n51
1129−197	15.839	15.526	15.307	15.002	0.009	0.010	0.009	0.010	0.312	0.219	0.306	0.524	2	2	2	2	c06
1129−197	15.842	15.359	14.903	14.647	0.011	0.090	0.372	0.275	0.483	0.456	0.256	0.712	1	1	1	1	c03
1135−096	18.124	17.556	17.069	16.531	0.067	0.059	0.035	0.007	0.568	0.487	0.538	1.024	2	2	2	2	c06
1135−096	18.173	17.195	16.688	···	0.014	0.013	0.036	···	0.978	0.507	9.900	9.900	1	1	1	0	n53
1135−096	18.327	17.665	17.175	16.606	0.030	0.015	0.012	0.012	0.662	0.490	0.569	1.059	1	1	1	1	c03
1140+413	16.580	15.663	15.210	14.652	0.014	0.012	0.014	0.012	0.917	0.453	0.558	1.011	1	1	1	1	n53
1141+219	15.764	15.485	15.212	15.080	0.118	0.060	0.018	0.161	0.279	0.273	0.132	0.406	2	2	2	2	c06
1141+219	17.986	···	···	···	0.014	···	···	···	9.900	···	···	···	1	0	0	0	c03
1141+219	15.979	15.368	15.182	···	0.061	0.078	0.090	···	0.611	0.186	9.900	9.900	1	1	1	0	n51
1143+115	17.119	16.777	16.470	15.974	0.029	0.024	0.017	0.018	0.342	0.307	0.496	0.803	1	1	1	1	c03
1143+115	17.160	16.711	16.402	15.730	0.012	0.012	0.036	0.044	0.449	0.309	0.672	0.981	1	1	1	1	n53
1159+292	···	···	15.641	15.081	···	···	0.022	0.012	···	9.900	0.560	9.900	0	0	1	1	n53
1159+292	17.219	···	16.365	15.787	0.109	···	0.093	0.084	9.900	9.900	0.578	9.900	1	0	1	1	n51
1208+457	15.703	15.378	15.161	14.947	0.045	0.037	0.034	0.048	0.325	0.217	0.214	0.431	1	1	1	1	n51
1208+457	15.820	15.528	15.253	15.023	0.013	0.012	0.014	0.012	0.292	0.275	0.230	0.505	1	1	1	1	n53
1213−136	15.861	15.552	15.305	15.054	0.019	0.001	0.001	···	0.309	0.247	0.251	0.498	2	2	2	2	c06
1214+141	14.383	14.107	13.960	13.649	0.061	0.078	0.090	0.055	0.276	0.147	0.311	0.458	1	1	1	1	n51
1214+141	14.762	14.506	14.128	13.865	0.150	0.108	0.056	0.032	0.256	0.377	0.264	0.641	2	2	2	2	c06
1214+141	14.783	14.585	14.274	14.072	0.027	0.013	0.011	0.011	0.198	0.311	0.202	0.513	1	1	1	1	c03
1218−013	17.654	17.271	16.815	16.263	0.043	0.039	0.040	0.032	0.383	0.456	0.552	1.008	2	2	2	2	c06
1218−013	18.073	17.596	17.165	···	0.013	0.013	0.036	···	0.477	0.431	9.900	9.900	1	1	1	0	n53
1219−018	17.494	16.927	16.462	15.945	0.009	0.018	0.007	0.015	0.567	0.465	0.516	0.982	2	2	2	2	c06
1221+044	18.198	17.938	17.707	17.390	0.030	0.022	0.030	0.034	0.260	0.231	0.317	0.548	1	1	1	1	c06
1223+477	17.181	16.707	16.387	15.790	0.070	0.036	0.037	0.107	0.474	0.320	0.597	0.917	1	1	1	1	n51
1223+477	17.218	16.692	16.389	15.806	0.030	0.027	0.033	0.001	0.526	0.303	0.583	0.886	2	2	2	2	n53
1225+322	16.555	15.011	14.424	13.679	0.013	0.013	0.022	0.011	1.544	0.587	0.745	1.332	1	1	1	1	n53
1225+322	17.837	···	14.356	13.995	0.110	···	0.093	0.084	9.900	9.900	0.361	9.900	1	0	1	1	n51
1228+282	16.336	···	15.172	···	0.011	···	0.024	···	9.900	9.900	9.900	···	1	0	4	0	n53
1229+021	12.686	12.627	12.475	11.974	0.027	0.013	0.011	0.010	0.059	0.152	0.501	0.653	1	1	1	1	c03
1229+021	12.728	12.658	12.500	12.003	0.010	0.005	0.004	0.003	0.071	0.158	0.497	0.654	2	2	2	2	c06
1229+021	12.728	12.658	12.500	12.003	0.010	0.005	0.004	0.003	0.071	0.158	0.497	0.654	2	2	2	2	c06
1230+013	14.681	14.516	14.358	14.108	0.009	0.013	0.002	0.008	0.165	0.158	0.250	0.408	2	2	2	2	c06

Table 2
(Continued)

Source	Mean *B*	Mean *V*	Mean *R*	Mean *I*	Stdd *B*	Stdd *V*	Stdd *R*	Stdd *I*	*B*−*V*	*V*−*R*	*R*−*I*	*V*−*I*	*nB*	*nV*	*nR*	*nI*	Epoch
1230+013	14.700	14.564	14.388	14.128	0.021	0.017	0.016	0.018	0.136	0.176	0.260	0.436	1	1	1	1	c03
1231+355	16.865	···	15.978	15.363	0.109	···	0.093	0.084	9.900	9.900	0.615	9.900	1	0	1	1	n51
1231+707	16.615	16.475	16.279	···	0.046	0.037	0.034	···	0.140	0.196	9.900	9.900	1	1	1	0	n51
1232−024	17.293	16.892	16.639	16.476	0.029	0.021	0.030	0.034	0.401	0.253	0.163	0.416	1	1	1	1	c06
1246−075	20.492	20.125	19.598	19.163	0.037	0.026	0.032	0.036	0.367	0.527	0.435	0.962	1	1	1	1	c06
1250+265	15.817	15.722	15.433	···	0.011	0.012	0.036	···	0.095	0.289	9.900	9.900	1	1	1	0	n53
1251+293	16.424	16.045	15.812	···	0.011	0.012	0.036	···	0.379	0.233	9.900	9.900	1	1	1	0	n53
1251+293	16.469	16.208	16.153	15.638	0.061	0.078	0.090	0.055	0.261	0.055	0.515	0.570	1	1	1	1	n51
1254+117	17.144	16.846	16.675	16.533	0.047	0.039	0.038	0.045	0.298	0.171	0.142	0.313	1	1	1	1	c06
1256−058	15.321	14.821	14.328	13.687	0.046	0.039	0.037	0.044	0.500	0.493	0.641	1.134	1	1	1	1	c06
1305−106	15.173	15.132	14.934	14.594	0.006	0.003	0.005	0.024	0.040	0.199	0.340	0.539	2	2	2	2	c06
1305−106	15.238	15.217	14.961	14.681	0.028	0.024	0.016	0.018	0.021	0.256	0.280	0.536	1	1	1	1	c03
1306+393	16.306	···	15.930	15.742	0.109	···	0.093	0.084	9.900	9.900	0.188	9.900	1	0	1	1	n51
1309+083	15.590	15.525	15.321	14.703	0.059	0.034	0.023	0.047	0.065	0.204	0.618	0.822	2	2	2	2	c06
1309+083	15.786	15.702	15.468	14.788	0.028	0.013	0.011	0.011	0.084	0.234	0.680	0.914	1	1	1	1	c03
1310+323	19.784	19.275	18.803	18.367	0.074	0.039	0.039	0.112	0.509	0.472	0.436	0.908	1	1	1	1	n51
1323+465	18.031	17.022	16.613	15.995	0.070	0.036	0.037	0.106	1.009	0.409	0.618	1.027	1	1	1	1	n51
1325−384	16.608	16.081	15.619	15.101	0.021	0.017	0.016	0.018	0.527	0.462	0.518	0.980	1	1	1	1	c03
1325−384	16.615	16.125	15.646	15.135	0.005	0.017	0.025	0.033	0.491	0.479	0.511	0.990	2	2	2	2	c06
1347+286	15.182	14.602	14.279	14.131	0.061	0.078	0.090	0.055	0.580	0.323	0.148	0.471	1	1	1	1	n51
1353+638	14.858	14.531	···	···	0.045	0.037	···	···	0.327	9.900	···	9.900	1	1	0	0	n51
1353+638	14.982	14.660	14.397	13.961	0.013	0.011	0.014	0.012	0.322	0.263	0.436	0.699	1	1	1	1	n53
1354+181	16.185	16.107	16.132	15.280	0.027	0.023	0.233	0.034	0.078	−0.025	0.852	0.827	1	1	2	1	c06
1354+181	16.579	16.395	···	···	0.012	0.013	···	···	0.184	9.900	···	9.900	1	1	0	0	n53
1356+253	16.517	16.223	16.039	15.383	0.061	0.078	0.090	0.055	0.294	0.184	0.656	0.840	1	1	1	1	n51
1356+253	16.529	16.283	16.062	···	0.011	0.012	0.036	···	0.246	0.221	9.900	9.900	1	1	1	0	n53
1359−419	15.071	15.123	14.900	14.483	0.036	0.050	0.039	0.048	−0.052	0.224	0.417	0.640	2	2	2	2	c06
1404+435	15.635	15.420	15.132	14.852	0.070	0.036	0.037	0.111	0.215	0.288	0.280	0.568	1	1	1	1	n51
1409+263	15.812	···	15.469	15.280	0.109	···	0.093	0.084	9.900	9.900	0.189	9.900	1	0	1	1	n51
1416−254	15.544	15.509	15.285	14.693	0.047	0.026	0.030	0.012	0.035	0.224	0.592	0.816	2	2	2	2	c06
1417+449	16.478	15.905	15.610	15.033	0.070	0.036	0.037	0.101	0.573	0.295	0.577	0.872	1	1	1	1	n51
1418−212	16.913	16.515	16.019	15.464	0.024	0.010	0.005	0.019	0.398	0.496	0.555	1.051	2	2	2	2	c06
1427+198	15.433	15.233	14.843	14.476	0.158	0.104	0.031	0.034	0.200	0.390	0.367	0.757	2	2	1	1	c06
1427+198	15.504	15.259	14.976	···	0.012	0.013	0.022	···	0.245	0.283	9.900	9.900	1	1	1	0	n53
1427+198	15.516	15.361	15.072	14.697	0.028	0.024	0.016	0.018	0.155	0.289	0.375	0.664	1	1	1	1	c03
1427+265	16.450	···	16.269	15.877	0.109	···	0.093	0.084	9.900	9.900	0.392	9.900	1	0	1	1	n51
1435+425	19.019	16.576	15.775	15.035	0.064	0.078	0.090	0.055	2.443	0.801	0.740	1.541	1	1	1	1	n51
1442+354	14.781	14.541	14.258	13.833	0.069	0.036	0.037	0.103	0.240	0.283	0.425	0.708	1	1	1	1	n51
1446+406	15.709	···	15.477	15.162	0.109	···	0.093	0.084	9.900	9.900	0.315	9.900	1	0	1	1	n51
1449+633	···	13.901	···	12.858	···	0.037	···	0.048	9.900	9.900	9.900	1.043	0	1	0	1	n51
1454−378	17.374	17.268	16.800	16.181	0.021	0.017	0.016	0.018	0.106	0.468	0.619	1.087	1	1	1	1	c03
1454−378	17.388	17.276	16.851	16.217	0.047	0.049	0.069	0.070	0.112	0.425	0.635	1.059	2	2	2	2	c06
1455−358	16.988	16.328	15.686	15.059	0.029	0.024	0.016	0.018	0.660	0.642	0.627	1.269	1	1	1	1	c03
1455−358	17.104	16.364	15.733	15.137	0.035	0.051	0.067	0.040	0.740	0.631	0.596	1.227	2	2	2	2	c06
1522−067	···	16.235	15.883	15.464	···	0.017	0.016	0.018	9.900	0.352	0.419	0.771	0	1	1	1	c03
1522−067	16.559	15.943	15.617	15.062	0.012	0.013	0.022	0.012	0.616	0.326	0.555	0.881	1	1	1	1	n53
1522−067	16.617	16.276	15.859	15.431	0.009	0.008	0.010	0.026	0.341	0.417	0.428	0.845	2	2	2	2	c06
1553+129	···	···	15.444	···	···	···	0.080	···	···	9.900	9.900	···	0	0	2	0	n54
1603+159	···	18.051	17.129	16.379	···	0.015	0.012	0.012	9.900	0.922	0.750	1.672	0	1	1	1	c03
1603+159	···	18.093	17.091	16.480	···	0.024	0.031	0.034	9.900	1.002	0.611	1.613	0	1	1	1	c06
1610+242	···	···	20.245	···	···	···	0.054	···	···	9.900	9.900	···	0	0	1	0	n54
1613+657	14.874	···	···	···	0.045	···	···	···	9.900	···	···	···	1	0	0	0	n51
1613+657	15.119	···	···	13.933	0.032	···	···	0.036	9.900	···	9.900	9.900	1	0	0	1	n54
1621+183	17.726	17.255	16.823	16.198	0.029	0.024	0.017	0.019	0.471	0.432	0.625	1.057	1	1	1	1	c03
1621+183	17.813	17.181	16.936	16.237	0.062	0.078	0.090	0.055	0.632	0.245	0.699	0.944	1	1	1	1	n51
1621+183	18.003	17.403	16.924	16.289	0.031	0.022	0.030	0.034	0.600	0.479	0.635	1.114	1	1	1	1	c06
1624−682	16.774	16.537	16.117	15.704	0.027	0.023	0.031	0.034	0.237	0.420	0.413	0.833	1	1	1	1	c06
1624−682	16.851	16.553	16.126	15.719	0.021	0.017	0.016	0.018	0.298	0.427	0.407	0.834	1	1	1	1	c03
1631+099	16.676	16.333	16.024	15.624	0.029	0.024	0.016	0.018	0.343	0.309	0.400	0.709	1	1	1	1	c03
1631+099	16.891	16.367	16.002	15.471	0.021	0.016	0.026	0.017	0.524	0.365	0.531	0.896	1	1	1	1	n54
1634+705	14.942	14.752	13.690	14.111	0.032	0.043	0.063	0.036	0.190	1.062	−0.421	0.641	1	1	1	1	n54
1634+705	14.970	14.653	···	14.021	0.045	0.037	···	0.048	0.317	9.900	9.900	0.632	1	1	0	1	n51
1700−262	···	···	···	15.756	···	···	···	0.011	···	···	9.900	9.900	0	0	0	1	c03
1701+518	15.267	15.012	14.692	14.280	0.029	0.020	0.021	0.019	0.255	0.320	0.412	0.732	1	1	1	1	n52
1701+518	15.374	14.980	14.714	14.269	0.045	0.037	0.034	0.048	0.394	0.266	0.445	0.711	1	1	1	1	n51
1704+607	15.697	15.460	15.155	···	0.045	0.037	0.034	···	0.237	0.305	9.900	9.900	1	1	1	0	n51

Table 2
(Continued)

Source	Mean B	Mean V	Mean R	Mean I	Stdd B	Stdd V	Stdd R	Stdd I	$B-V$	$V-R$	$R-I$	$V-I$	nB	nV	nR	nI	Epoch
1704+607	15.743	15.564	15.187	14.859	0.029	0.020	0.021	0.019	0.179	0.377	0.328	0.705	1	1	1	1	n52
1719+481	15.265	14.815	14.514	···	0.070	0.036	0.037	···	0.450	0.301	9.900	9.900	1	1	1	0	n51
1723+343	16.046	···	15.679	15.000	0.109	···	0.093	0.084	9.900	9.900	0.679	9.900	1	0	1	1	n51
1728−143	14.759	14.199	13.760	12.979	0.021	0.017	0.016	0.018	0.560	0.439	0.781	1.220	1	1	1	1	c03
1728−143	14.896	14.228	13.816	13.048	0.021	0.016	0.025	0.017	0.668	0.412	0.768	1.180	1	1	1	1	n54
1751+097	17.982	17.391	16.741	15.964	0.029	0.024	0.016	0.018	0.591	0.650	0.777	1.427	1	1	1	1	c03
1803−651	···	···	16.614	16.120	···	···	0.011	0.042	···	9.900	0.494	9.900	0	0	1	4	c03
1818+537	15.117	14.865	14.750	14.473	0.061	0.078	0.090	0.055	0.252	0.115	0.277	0.392	1	1	1	1	n51
1821+643	13.682	13.688	13.568	13.172	0.069	0.036	0.037	0.072	−0.006	0.120	0.396	0.516	1	1	1	1	n51
1824+107	17.363	···	16.508	16.135	0.021	···	0.016	0.018	9.900	9.900	0.373	9.900	1	0	1	1	c03
1824+107	17.598	17.179	16.665	16.309	0.021	0.016	0.026	0.017	0.419	0.514	0.356	0.870	1	1	1	1	n54
1826+018	···	···	18.615	17.740	···	···	0.018	0.019	···	9.900	0.875	9.900	0	0	1	1	c03
1827+345	18.568	17.908	17.456	16.937	0.062	0.078	0.090	0.055	0.660	0.452	0.519	0.971	1	1	1	1	n51
1832+139	···	···	19.562	···	···	···	0.160	···	···	9.900	9.900	···	0	0	2	0	n54
1830+732	14.177	14.033	13.880	13.294	0.069	0.036	0.037	0.045	0.144	0.153	0.586	0.739	1	1	1	1	n51
1832+286	19.203	18.503	18.455	17.999	0.063	0.078	0.091	0.056	0.700	0.048	0.456	0.504	1	1	1	1	n51
1834+209	18.485	17.220	16.697	16.125	0.030	0.024	0.016	0.018	1.265	0.523	0.572	1.095	1	1	1	1	c03
1850+284	18.190	18.031	17.840	17.383	0.022	0.017	0.026	0.018	0.159	0.191	0.457	0.648	1	1	1	1	n54
1853+237	16.116	15.776	13.318	14.920	0.032	0.043	0.063	0.036	0.340	2.458	−1.602	0.856	1	1	1	1	n54
1853+237	16.302	15.571	15.159	14.731	0.028	0.024	0.016	0.018	0.731	0.412	0.428	0.840	1	1	1	1	c03
1902+320	17.804	17.233	16.506	15.376	0.022	0.016	0.026	0.017	0.571	0.727	1.130	1.857	1	1	1	1	n54
1912+053	···	···	19.421	···	···	···	0.053	···	···	9.900	9.900	···	0	0	1	0	n54
1911−201	18.920	18.365	17.862	···	0.023	0.018	0.017	···	0.555	0.503	9.900	9.900	1	1	1	0	c03
1939−100	18.613	17.185	16.512	15.696	0.030	0.024	0.016	0.018	1.428	0.673	0.816	1.489	1	1	1	1	c03
1939−100	18.985	17.303	17.442	16.437	0.035	0.043	0.063	0.036	1.682	−0.139	1.005	0.866	1	1	1	1	n54
1950+081	···	···	20.143	···	···	···	0.053	···	···	9.900	9.900	···	0	0	1	0	n54
2007+405	22.028	20.060	19.375	···	0.049	0.024	0.023	···	1.968	0.685	9.900	9.900	1	1	1	0	n52
2024+173	18.602	18.184	17.825	17.669	0.023	0.018	0.017	0.019	0.418	0.359	0.156	0.515	1	1	1	1	c03
2024+173	19.163	19.571	···	···	0.025	0.021	···	···	−0.408	9.900	···	9.900	1	1	0	0	n54
2051+747	···	···	19.477	···	···	···	0.143	···	···	9.900	9.900	···	0	0	2	0	n54
2100+238	19.828	19.501	19.324	19.231	0.032	0.018	0.018	0.019	0.327	0.177	0.093	0.270	1	1	1	1	n52
2112−387	···	17.364	16.905	16.201	···	0.025	0.024	0.054	9.900	0.459	0.704	1.163	0	1	1	1	c02
2115+191	16.308	16.252	16.025	15.817	0.029	0.020	0.021	0.019	0.056	0.227	0.208	0.435	1	1	1	1	n52
2124−177	15.787	15.491	15.235	14.909	0.023	0.027	0.028	0.068	0.296	0.256	0.326	0.582	1	1	1	1	c02
2130+335	···	22.648	21.451	···	···	0.046	0.030	···	9.900	1.197	9.900	9.900	0	1	1	0	n52
2149−447	16.646	16.335	15.997	15.683	0.022	0.019	0.023	0.079	0.311	0.338	0.314	0.652	1	1	1	1	c02
2155+228	···	···	20.467	···	···	···	0.053	···	···	9.900	9.900	···	0	0	1	0	n54
2202−570	17.072	16.488	16.024	15.472	0.024	0.024	0.024	0.054	0.584	0.464	0.552	1.016	1	1	1	1	c02
2207+169	···	···	20.674	···	···	···	0.143	···	···	9.900	9.900	···	0	0	2	0	n54
2213−649	17.317	16.689	16.138	15.614	0.024	0.027	0.028	0.068	0.628	0.551	0.524	1.075	1	1	1	1	c02
2217+243	···	···	17.757	···	···	···	0.015	···	···	9.900	9.900	···	0	0	2	0	n54
2217+142	15.107	14.632	14.147	···	0.028	0.014	0.014	···	0.475	0.485	9.900	9.900	1	1	1	0	n52
2220+398	18.483	···	18.024	17.578	0.029	···	0.021	0.019	9.900	9.900	0.446	9.900	1	0	1	1	n52
2245−469	15.405	15.177	14.950	14.420	0.152	0.151	0.137	0.120	0.228	0.227	0.530	0.757	1	1	1	1	c02
2245−606	16.195	15.746	15.500	15.219	0.152	0.151	0.137	0.120	0.449	0.246	0.281	0.527	1	1	1	1	c02
2248−681	···	17.148	16.570	15.942	···	0.027	0.028	0.069	9.900	0.578	0.628	1.206	0	1	1	1	c02
2253+197	···	···	16.340	···	···	···	0.056	···	···	9.900	9.900	···	0	0	2	0	n54
2300−558	···	17.340	16.743	15.992	···	0.020	0.014	0.054	9.900	0.597	0.751	1.348	0	1	2	1	c05
2300−558	18.274	17.233	16.708	15.982	0.026	0.024	0.024	0.054	1.041	0.525	0.726	1.251	1	1	1	1	c02
2304−087	14.549	14.345	13.899	13.595	0.009	0.033	0.001	0.062	0.204	0.446	0.304	0.750	2	1	2	1	c05
2312+388	18.605	18.345	17.942	17.280	0.030	0.021	0.022	0.019	0.260	0.403	0.662	1.065	1	1	1	1	n52
2313+472	18.106	17.725	17.288	···	0.029	0.021	0.021	···	0.381	0.437	9.900	9.900	1	1	1	0	n52
2339−554	15.639	15.456	15.186	15.042	0.012	0.014	0.007	0.005	0.183	0.269	0.144	0.414	3	3	3	3	c05
2339−554	15.655	15.439	15.205	15.066	0.023	0.027	0.028	0.068	0.216	0.234	0.139	0.373	1	1	1	1	c02
2351−012	15.469	15.439	15.174	14.487	0.002	0.031	0.011	0.019	0.030	0.265	0.687	0.952	2	1	2	1	c05
2352+033	18.269	17.556	17.004	16.453	0.041	0.030	0.005	0.031	0.713	0.552	0.551	1.103	1	1	2	1	c05
2358+494	17.660	17.407	17.070	16.620	0.024	0.017	0.014	0.017	0.253	0.337	0.450	0.787	1	1	1	1	n52
2359+086	17.184	16.278	15.772	15.193	0.008	0.031	0.002	0.020	0.906	0.506	0.579	1.085	2	1	2	1	c05
2359+086	17.209	15.948	15.416	14.761	0.029	0.014	0.014	0.015	1.261	0.532	0.655	1.187	1	1	1	1	n52

(This table is also available in machine-readable and Virtual Observatory (VO) forms in the online journal.)

reference frame link program (Zacharias & Zacharias 2005) was adopted for processing of both the CTIO 1 m and NOFS 1 m data. Image centroids were obtained from two-dimensional Gaussian profile least-squares fits to the pixel counts of detected

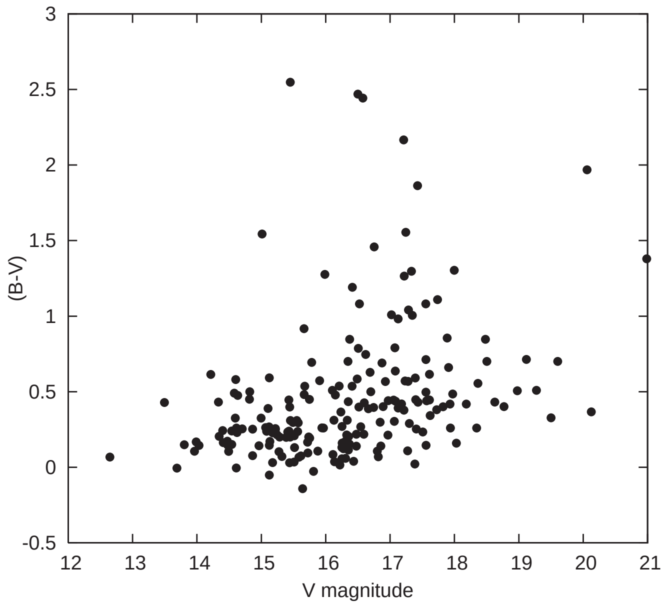

Figure 2. Plot of observed ($B-V$) color vs. observed V magnitude.

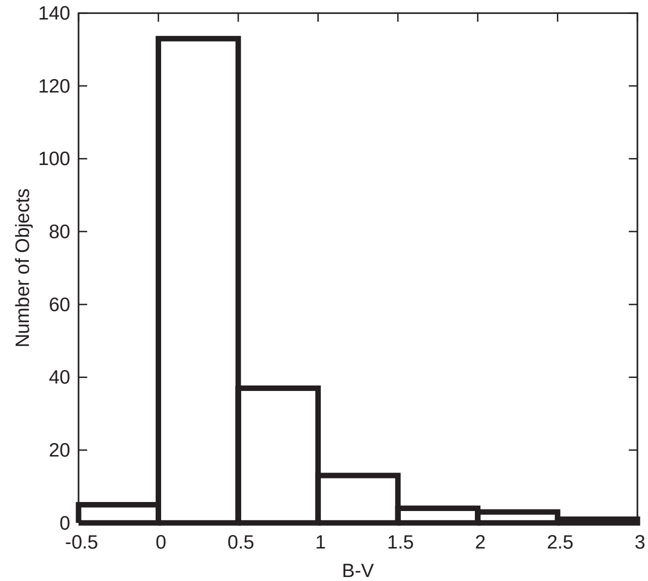

Figure 4. Histogram of observed ($B-V$) color distribution.

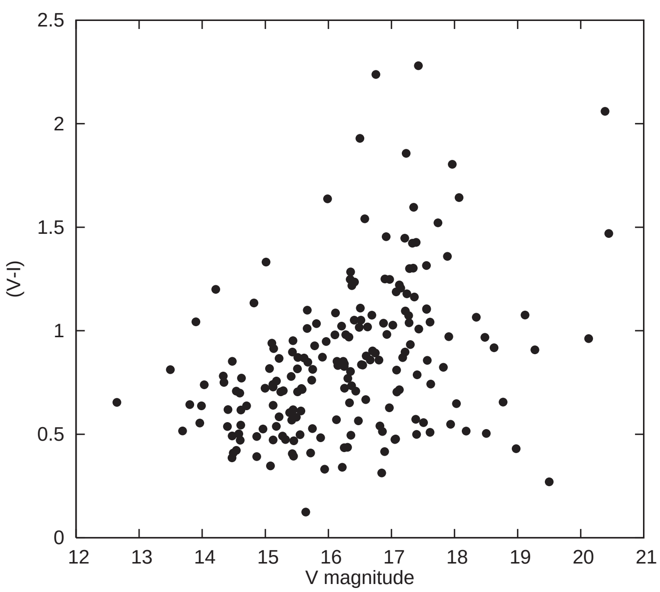

Figure 3. Plot of observed ($V-I$) color vs. observed V magnitude.

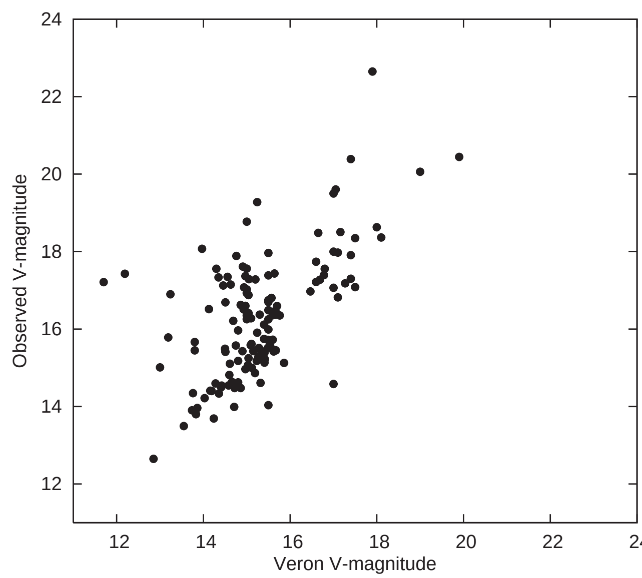

Figure 5. Plot of observed V magnitudes vs. Veron catalog V magnitudes.

sources. The UCAC2 catalog (Zacharias et al. 2004) provided the reference stars for the astrometric reductions. An eight-parameter plate model was used for astrometric reduction after determining and applying corrections for atmospheric refraction and mean optical field angle distortion.

There are dedicated, high accuracy, astrometric observations going on at the 61 inch telescope at NOFS (Zacharias & Zacharias 2008; Zacharias et al. 2008) with results to be published in 2010 for about 12 sources on the few milliarcsecond level. A set of over 200 QSOs has been observed at somewhat lower accuracy with respect to UCAC3 reference stars, which will be published in 2009.

3.3. Photometric Data Processing

Instrumental magnitudes were obtained from aperture photometry performed on each detected object as part of the astrometric pipeline. Pixel counts in the background ring were sorted and outliers excluded before deriving the mean local background. Photometric standard fields were observed typically 3–5 times a night at various air masses. Photometric calibration per filter was performed with the Landoldt stars (Landolt 1992) and a two- or three-parameter model determining the zero point and linear terms as a function of air mass and color (if needed), respectively, was constructed. The decision to include a color term was based on results from test reductions for each filter and night, at which time also outliers and potential problems were identified. Least-square fit results and residuals were examined to determine the photometric quality of the night. The 1σ error on the photometric fit had a median value of 35, 32, 37, and 35 mmag, and the extinction had a median value of -0.268, -0.155, -0.105, and -0.056 for the B, V, R, and I bands, respectively. Color coefficients were not used for 60% of our nights. Their typical value, when used, was -0.058. For acceptable data, the derived photometric calibration parameters were applied to the QSO target observations to obtain individual B, V, R, and I magnitudes.

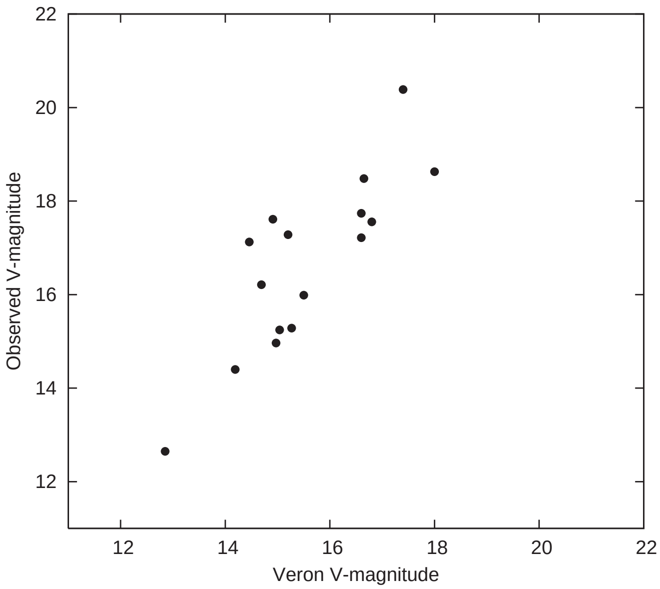

Figure 6. Plot of observed V magnitudes vs. Veron catalog V magnitude for those sources observed at three or more epochs.

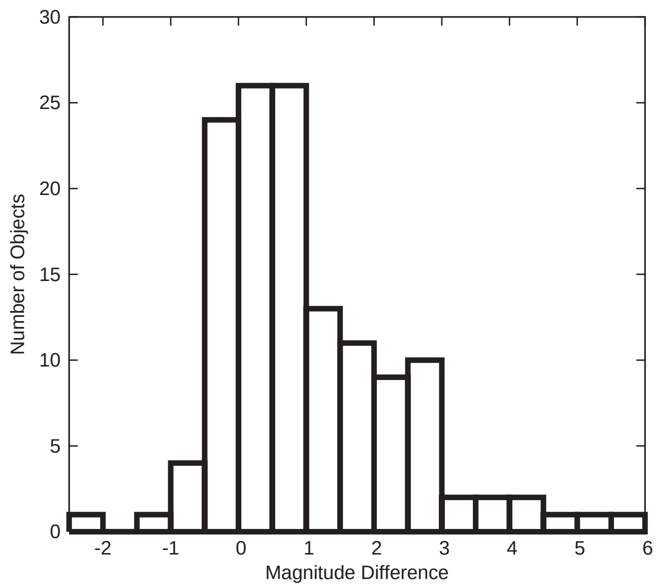

Figure 7. Histogram of magnitude differences between observed V magnitudes and Veron catalog V magnitudes. A positive difference indicates a larger observed V magnitude (fainter) as compared to the Veron value.

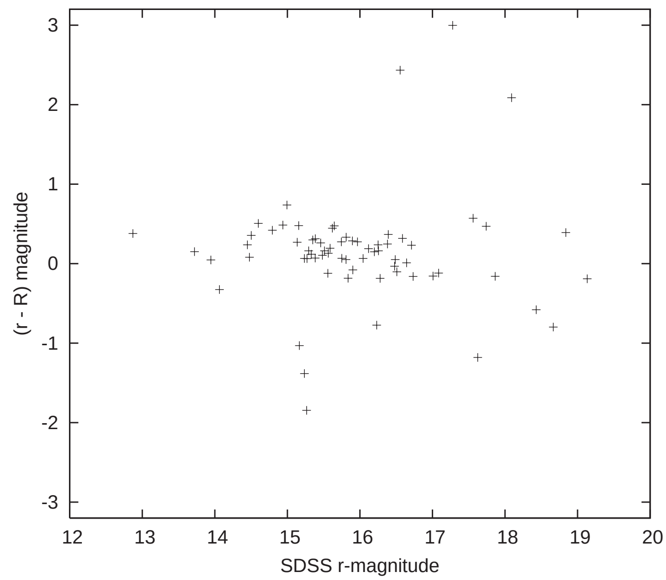

Figure 8. Plot of $(r-R)$, the difference of the SDSS r magnitude and observed R magnitude, against SDSS r magnitude

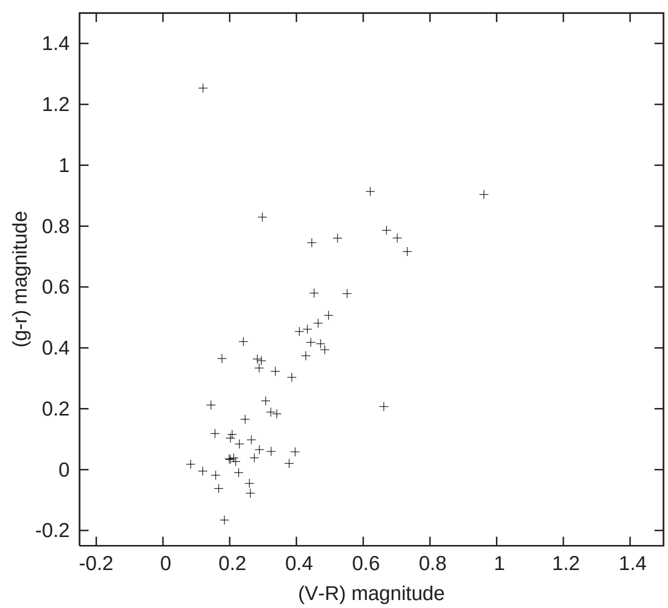

Figure 9. Color–color plot of SDSS $(g-r)$ against observed $(V-R)$.

Color information of the QSO targets were initially not available, and a mean color was adopted for the first photometric calibration step. After deriving preliminary magnitudes in all bands, colors were derived and iteratively used in the photometric calibrations for subsequent processing to arrive at the final target magnitudes.

4. RESULTS

4.1. Distribution of Targets

Figure 1 shows the observed sources in the sky, coded by symbol for groups of R magnitude. The plot shows that the sources are well distributed over the sky; however, the area near the galactic plane (as expected) is significantly more sparsely populated than the rest of the sky. In sky areas with a large number of sources, a reference frame target source can be selected from a number of candidates depending on further investigations. For areas close to the galactic plane, the choices are limited and often only a target of 18th or fainter magnitude is available. However, even if a relatively bright target cutoff limit has to be adopted, the sky distribution of sources is sufficiently homogeneous to support a highly accurate future reference frame (V. V. Makarov 2008, private communication).

4.2. Mean Magnitudes

Individual magnitudes of our target sources were collected and averaged (per filter) for multiple observations over the period of an observing run, which typically extended to a few nights. In a few cases, a larger than expected scatter was observed. From the combined data, a fraction of the nights were identified with nonphotometric conditions and all data points obtained during that period of time were excluded. The final results for each object and each observing run are presented in

Table 3
Magnitude Variability

Source	Runs	*B* magnitude			*V* magnitude			*R* magnitude			*I* magnitude		
		Mean	Error[a]	Scatter	Mean	Error	Scatter	Mean	Error	Scatter	Mean	Error	Scatter
0504−297	3	16.234	0.032	0.032	16.220	0.024	0.037	16.155	0.024	0.031	15.880	0.054	0.028
0517−442	3	15.475	0.023	0.038	15.219	0.027	0.021	14.868	0.028	0.027	14.353	0.068	0.009
0534−603	3	18.108	0.153	0.027	17.125	0.151	0.024	16.485	0.137	0.006	15.904	0.120	0.015
0536−517	3	16.748	0.024	0.042	16.210	0.027	0.039	15.781	0.028	0.022	15.189	0.068	0.025
0552−532	3	15.938	0.023	0.023	15.737	0.027	0.006	15.361	0.028	0.008	14.976	0.068	0.003
0552−640	3	15.460	0.152	0.107	15.245	0.151	0.099	14.910	0.137	0.020	14.539	0.120	0.037
0556−027	3	...	...	...	20.386	0.025	0.152	19.120	0.113	0.095	18.257	0.046	0.147
0559−504	3	15.105	0.024	0.017	14.963	0.024	0.013	14.816	0.024	0.013	14.438	0.054	0.028
0607−086	4	18.208	0.076	0.056	16.754	0.027	0.030	15.739	0.036	0.037	14.516	0.068	0.018
0611−194	3	18.845	0.032	0.049	17.737	0.148	0.091	17.069	0.029	0.046	16.215	0.068	0.024
0646−443	4	17.602	0.025	0.087	17.216	0.024	0.043	16.939	0.024	0.038	16.320	0.054	0.022
0648−177	4	19.856	0.063	0.124	19.118	0.033	0.047	18.540	0.029	0.050	18.042	0.087	0.078
0718−261	4	19.058	0.054	0.015	18.627	0.060	0.035	18.180	0.024	0.022	17.709	0.058	0.006
0745−007	3	17.518	0.022	0.031	17.126	0.017	0.043	16.834	0.025	0.015	16.827	0.025	...
0827+097	4	17.263	0.046	0.035	15.987	0.090	0.042	15.228	0.035	0.028	14.426	0.013	0.006
0828−708	3	19.294	0.036	...	18.481	0.027	0.047	18.003	0.034	0.030	17.513	0.058	0.058
0850−122	3	18.052	0.080	0.030	17.556	0.175	0.131	17.202	0.055	0.053	16.450	0.164	0.125
0922−400	3	17.965	0.029	0.064	17.623	0.021	0.063	17.378	0.030	0.057	16.881	0.037	0.056
1135−096	3	18.208	0.067	0.075	17.472	0.059	0.174	16.977	0.036	0.181	16.569	0.012	0.053
1214+141	3	14.643	0.150	0.159	14.399	0.108	0.181	14.121	0.090	0.111	13.862	0.055	0.150
1229+021	3	12.714	0.027	0.017	12.648	0.013	0.013	12.492	0.011	0.010	11.993	0.010	0.012
1427+198	3	15.484	0.158	0.032	15.284	0.104	0.048	14.964	0.031	0.081	14.587	0.034	0.156
1522−067	3	16.588	0.012	0.041	16.151	0.017	0.128	15.785	0.022	0.104	15.319	0.026	0.158
1621+183	3	17.847	0.062	0.100	17.280	0.078	0.080	16.894	0.090	0.044	16.241	0.055	0.032

Note.
[a] The largest formal error is shown.

Table 4
Formal Error Statistics

Filter	Number of Objects	Error $\leqslant 5\%$	Median Error	Largest Error
B	130	107	0.021	0.44
V	128	102	0.020	0.54
R	142	112	0.018	0.56
I	131	100	0.025	0.60

Table 2. In this table, the first column has the J2000.0 name of the target, columns 2–5 have the mean magnitudes per run for *B*, *V*, *R*, and *I* filters, respectively. Columns 6–9 have the respective standard errors per epoch, a value of "..." indicates no measurement through that particular filter. Columns 10–13 show the $(B-V)$, $(V-R)$, $(R-I)$, and $(V-I)$ colors, respectively. Columns 14–17 show the number of times the object was observed with a particular filter. The final column records the epoch label (observing run, see Table 1).

4.3. Colors

Figures 2 and 3 show the observed $(B-V)$ and $(V-I)$ colors, respectively. A large range of colors is observed with five targets having $(B-V)\leqslant 0$, 170 targets in the 0–1 range, and 21 targets in the $\geqslant 1$ range, respectively (Figure 4). This is expected for a sample of QSOs with a large spread in redshift. This color knowledge is important for future reference frame target selection. To optimize the expensive integration time of missions like SIM, a prediction of the target brightness in the instrumental system will be required on the few tenths magnitude level. Our *B*, *V*, *R*, and *I* results span the expected bandpass of the SIM mission to allow this brightness estimate; however, more observations near the mission epoch will be required to take variability into account.

4.4. Comparison with Veron

Figure 5 shows our observed *V* magnitudes compared with *V* magnitudes from the VCV06 for the 134 sources where they were available. Figure 6 shows our observed *V* magnitudes for those 16 sources which were observed at three or more epochs and for which VCV06 *V* magnitudes were available. Both Figures 5 and 6 show large differences between the Veron-Cetty and our observed magnitudes, sometimes exceeding 2 mag in either direction. The histogram in Figure 7 shows the distribution of *V* magnitude difference between our observations and the Veron catalog. The internal errors of our observations are typically below 0.1 mag, while the errors of the Veron magnitudes are typically not known. Still differences of more than 2 mag suggest mainly not a random observational error issue, rather being a physical change in brightness of the targets. This underlines the requirement for more, dedicated observations at an epoch of interest and clearly shows that a brightness lookup in some published table is not adequate for the task of scheduling SIM mission time to observe those targets or even to select targets to a desired limiting magnitude.

4.5. Comparison with SDSS

We also made a comparison of our results with a dedicated sample, the Sloan Digital Sky Survey (SDSS DR5; Adelman-McCarthy et al. 2007). Using a list of our object right ascensions and declinations in decimal degrees, we made an "object cross id" type of search of the SDSS DR5 which yielded ~85 matches. We then checked that the positions of these matches were within

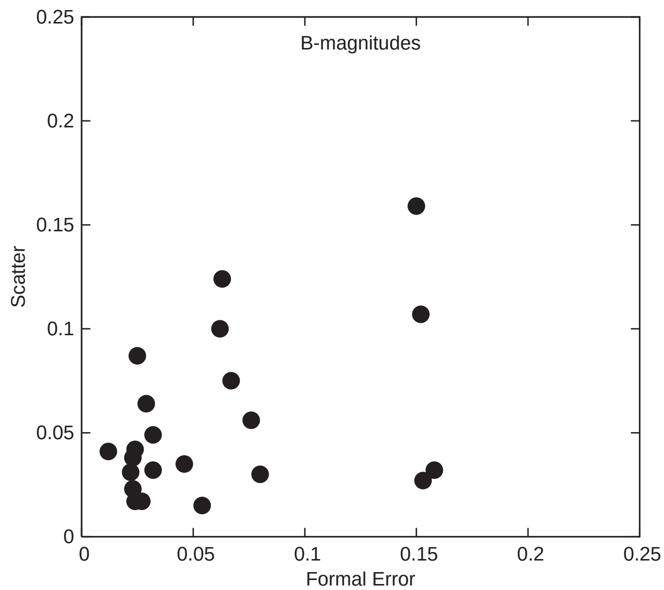

Figure 10. Scatter in the *B*-band data as a function of largest formal error.

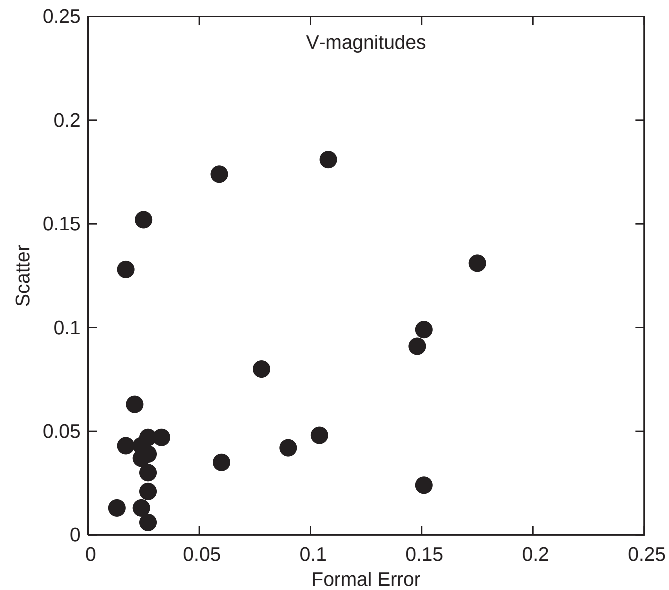

Figure 11. Scatter in the *V*-band data as a function of largest formal error.

1 arcsec of our quasar positions and were left with a list of 71 matches we could use for comparison.

Figure 8 is a plot of $(r - R)$, the difference of the SDSS r magnitude and our R magnitude, against SDSS r magnitude for the 71 sources they were available. It shows relatively small differences between our observed R magnitudes and the SDSS r magnitudes down to r magnitudes of about 19. The three sources fainter than this were outliers and are not included in the plot. It is possible that these three are mismatches. Figure 9 shows a color–color plot of the SDSS $(g-r)$ against our $(V - R)$. Two outliers, both with very large negative $(g-r)$ value, are not shown. This plot shows good agreement between the SDSS magnitudes and those presented here.

4.6. Variability

All our 235 sources are observed at least once in most of the filters. Many sources have multiple epoch observations. There were 24 sources that were observed in 3 or more observing runs and the scatter in their mean magnitudes was calculated and is shown in Table 3 together with their overall mean magnitudes, i.e., averaged over all observing runs, and the largest formal error of a magnitude per observing run. The formal error and the scatter columns are directly comparable to look for a possible, physical variability of a source. However, at this point we have only few epochs of a light curve and we are dealing with small number statistics.

5. DISCUSSION

The goal of about 5% photometric error per epoch was achieved for most sources, which is sufficient for the purpose of predicting the brightness of our targets in any instrumental system between B and I on the 10% level to optimize future mission target selection and integration time.

Internal, photometric errors were calculated for single observations. The errors given are the RSS (root-square-sum) of an assumed systematic error floor of 0.01 mag, the Poisson noise error, and the nightly fit error to the standard stars. Most targets are well exposed with low random noise errors (about 0.01 mag); thus, the nightly fit error dominates the photometric error of individual observations.

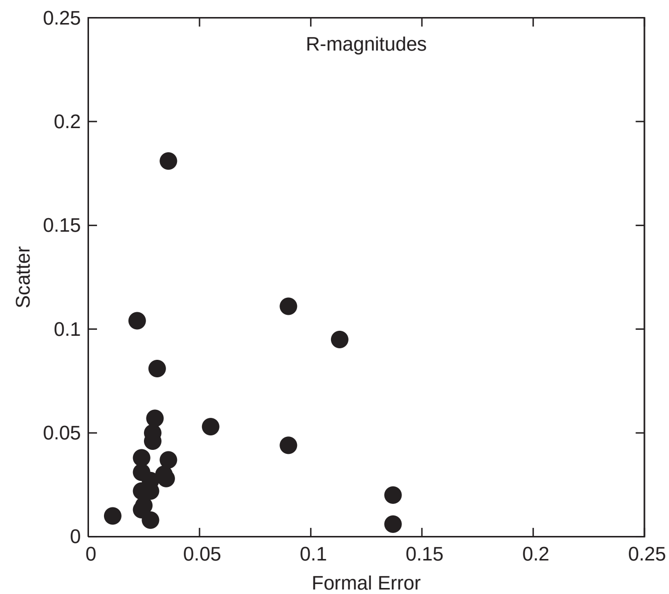

Figure 12. Scatter in the *R*-band data as a function of largest formal error.

Table 4 lists results for cases with formal error estimates from more than 1 observation per epoch and filter. Columns 2 and 3 show the total number of such cases (per filter) and the number of cases with a formal photometry error (1σ) of less than or equal to 5%. The last two columns give the median and largest formal error of each sample, respectively. This shows that our goal of reaching a few percent precision has been achieved on most targets.

Figures 10–13 display our variability investigation results. For each filter (B, V, R, and I), the observed scatter (over different epochs) is plotted versus the largest, internal, formal error of all observed epochs. The strongest indication of variability is seen for source 0552-640 with B and V scatter of about 0.1 mag and formal error of 0.01 mag. Several other sources show a ratio of scatter to formal error of about 3, but more observations are required to characterize the photometric data for variability or draw any conclusions.

The largest observed scatter is about 0.2 mag over the few years of our observing program, which is in stark contrast to

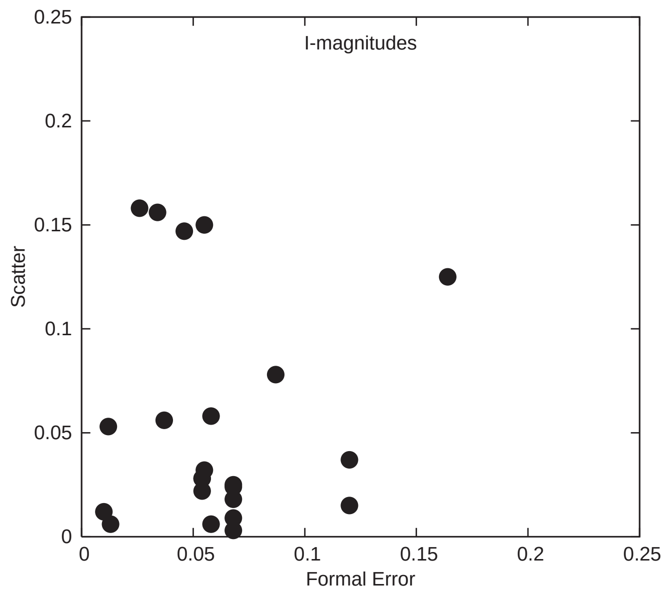

Figure 13. Scatter in the *I*-band data as a function of largest formal error.

some of the differences seen between the Veron-Cetty listed magnitudes and our observations.

The errors in the photometric calibration of the data of a typical acceptable night are on the order of 20–50 mmag for all filters. This holds for the least-squares fit error as well as for the standard error of the derived photometric zero-point constant. Thus, the observed discrepancies between our observations and the Veron-Cetty catalog, as well as the indication for variability seem to be of physical nature.

6. CONCLUSIONS/SUMMARY

A sample of extragalactic, compact sources, mainly QSOs, has been observed to characterize the photometric stability of these sources to better than 5%. Of the 134 sources that have *V* magnitudes in the Veron & Veron-Cetty catalog, a difference of over 1.0 mag is found for the observed-catalog magnitudes for about 36% of the common sources, and 10 sources show over 3 mag difference. As expected, the largest problem in this context is the intrinsic photometric variability of these sources, which will require multiple observations at different epochs to downselect “stable” candidates and furthermore will likely require additional observations close to the epoch of a future mission.

Although this program is driven by SIM preparatory science goals, our observations are of general interest providing accurate magnitudes and colors for a large sample of QSO targets at current epochs. An optical quasar monitoring program, as, e.g., proposed by J. Schramm (about 1980; Borgeest & Schramm 1994) is desirable. The current paper mainly forms the baseline providing mean *B*, *V*, *R*, and *I* measures at one or few epochs. At least for the brighter subset of our candidates such a program could be undertaken in a collaboration with adequately equipped amateur astronomers. We plan to continue our photometric quasar monitoring program in order to obtain optical variability information on these targets.

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REFERENCES

Adelman-McCarthy, J., et al. 2007, ApJS, 172, 634
Bachev, R. S. 2009, A&A, 493, 907
Bauer, A., Baltay, C., Coppi, P., Ellman, N., Jerke, J., Rabinowitz, D., & Scalzo, R. 2009, ApJ, 696, 1241
Borgeest, U., & Schramm, K.-J. 1994, A&A, 284, 764
Gaume, R. A., Jr., et al. 2009, BAAS, 41, 344
Johnston, K. J., et al. 1995, AJ, 110, 880
Landolt, A. U. 1992, AJ, 104, 340
Ma, C., et al. 1998, AJ, 116, 516
Makarov, V. V., Johnston, K. J., & Zacharias, N. 2006, AAS DDA meeting 37, paper 14.02, BAAS, 38, 675
Unwin, S. C., et al. 2008, PASP, 120, 38
Unwin, S. C., et al. 2009, SIMLite Astrometric Observatory: From Earth-like Planets to Dark Matter (Pasadena, CA: NASA Jet Propulsion Laboratory, California Institute of Technology)
Vanden Berk, D. E., et al. 2004, ApJ, 601, 692
Véron-Cetty, M.-P., & Véron, P. 2006, A&A, 455, 773
Wilhite, B. C., Brunner, R. J., Grier, C. J., Schneider, D. P., & vanden Berk, D. E. 2008, MNRAS, 383, 1232
Zacharias, M. I., & Zacharias, N. 2005, in ASP Conf. Ser. 338, Astrometry in the Age of the Next Generation of Large Telescopes, ed. K. Seidelmann & A. K. B. Monet (San Francisco, CA: ASP), 184
Zacharias, M. I., & Zacharias, N. 2008, in Proc. IAU Symp. 248, A Giant Step: From Milli- to Micro-arcsecond Astrometry, ed. W. Jin, I. Platais, & M. A. C. Perryman (Cambridge: Cambridge Univ. Press), 332
Zacharias, N., Urban, S. E., Zacharias, M. I., Wycoff, G. L., Hall, D. M., Monet, D. G., & Rafferty, T. J. 2004, AJ, 127, 3043
Zacharias, N., Zacharias, M. I., Boboltz, D., Fey, A., Gaume, R., Hennessy, G., Johnston, K. J., & Ojha, R. 2008, in Proc. Journées 2007 Systemes de Reference Spatio-Temporels, Extragalactic Optical-Radio Link Research at USNO, ed. N. Capitaine (Paris: Observatoire de Paris), 28